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(71) BASF AKTIENGESELLSCHAFT,  
D-67056, LUDWIGSHAFEN, XX (DE).

(72) FUCHS, EBERHARD (DE).  
FLICK, KLEMENS (DE).

(74) ROBIC

(54) UTILISATION DE CORPS MOULES COMME CATALYSEUR POUR LA PRODUCTION DE CAPROLACTAME  
(54) USE OF SHAPED BODIES AS A CATALYST FOR THE PRODUCTION OF CAPROLACTAM

(57)

The invention relates to the use of essentially shaped bodies containing a catalytically active oxide as a catalyst comprising no soluble constituent, under the reaction conditions, for the production of cyclic lactams by reacting aminocarboxylic acid nitriles with water in aqueous phase, in a fixed bed reactor. This catalyst is composed of shaped bodies which can be obtained by shaping the oxide into shaped bodies and by treating the oxide with an acid which is hardly soluble, having 0.1 to 30 % by weight of the oxide, before or after the shaping process.



- (72) FUCHS, EBERHARD, DE  
(72) FLICK, KLEMENS, DE  
(71) BASF AKTIENGESELLSCHAFT, DE  
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(30) 1997/09/03 (19738464.1) DE  
(54) **UTILISATION DE CORPS MOULÉS COMME CATALYSEUR  
POUR LA PRODUCTION DE CAPROLACTAME**  
(54) **USE OF SHAPED BODIES AS A CATALYST FOR THE  
PRODUCTION OF CAPROLACTAM**

(57) L'invention concerne l'utilisation essentiellement de corps moulés contenant un oxyde catalytiquement actif comme catalyseur ne présentant, dans les conditions de réaction, aucun constituant soluble, pour la production de lactames cycliques par réaction de nitriles d'acide aminocarboxylique avec de l'eau en phase liquide, dans un réacteur à lit fixe. Ce catalyseur est constitué de corps moulés que l'on peut obtenir par moulage de l'oxyde, qui donne des corps moulés, et traitement dudit oxyde avant ou après le moulage avec 0,1 à 30 % en poids, par rapport à l'oxyde, d'un acide dans lequel celui-ci est difficilement soluble.

(57) The invention relates to the use of essentially shaped bodies containing a catalytically active oxide as a catalyst comprising no soluble constituent, under the reaction conditions, for the production of cyclic lactams by reacting aminocarboxylic acid nitriles with water in aqueous phase, in a fixed bed reactor. This catalyst is composed of shaped bodies which can be obtained by shaping the oxide into shaped bodies and by treating the oxide with an acid which is hardly soluble, having 0.1 to 30 % by weight of the oxide, before or after the shaping process.





**PCT**  
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<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; padding: 5px;"> <p>(21) Internationales Aktenzeichen: <b>PCT/EP98/05333</b></p> <p>(22) Internationales Anmeldedatum: <b>21. August 1998 (21.08.98)</b></p> <p>(30) Prioritätsdaten: <b>197 38 464.1      3. September 1997 (03.09.97)      DE</b></p> <p>(71) Anmelder (für alle Bestimmungsstaaten ausser US): <b>BASF AKTIENGESELLSCHAFT [DE/DE]; D-67056 Ludwigshafen (DE).</b></p> <p>(72) Erfinder; und (75) Erfinder/Anmelder (nur für US): <b>FUCHS, Eberhard [DE/DE]; Bensheimer Ring 5c, D-67227 Frankenthal (DE). FLICK, Klemens [DE/DE]; Am Bildstöckel 16, D-76863 Herxheim (DE).</b></p> <p>(74) Gemeinsamer Vertreter: <b>BASF AKTIENGESELLSCHAFT; D-67056 Ludwigshafen (DE).</b></p> </td> <td style="width: 50%; vertical-align: top; padding: 5px;"> <p>(81) Bestimmungsstaaten: <b>AL, AU, BG, BR, BY, CA, CN, CZ, GE, HU, ID, IL, JP, KR, KZ, LT, LV, MK, MX, NO, NZ, PL, RO, RU, SG, SI, SK, TR, UA, US, eurasisches Patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</b></p> <p><b>Veröffentlicht</b> <i>Mit internationalem Recherchenbericht. Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist; Veröffentlichung wird wiederholt falls Änderungen eintreffen.</i></p> </td> </tr> </table>			<p>(21) Internationales Aktenzeichen: <b>PCT/EP98/05333</b></p> <p>(22) Internationales Anmeldedatum: <b>21. August 1998 (21.08.98)</b></p> <p>(30) Prioritätsdaten: <b>197 38 464.1      3. September 1997 (03.09.97)      DE</b></p> <p>(71) Anmelder (für alle Bestimmungsstaaten ausser US): <b>BASF AKTIENGESELLSCHAFT [DE/DE]; D-67056 Ludwigshafen (DE).</b></p> <p>(72) Erfinder; und (75) Erfinder/Anmelder (nur für US): <b>FUCHS, Eberhard [DE/DE]; Bensheimer Ring 5c, D-67227 Frankenthal (DE). FLICK, Klemens [DE/DE]; Am Bildstöckel 16, D-76863 Herxheim (DE).</b></p> <p>(74) Gemeinsamer Vertreter: <b>BASF AKTIENGESELLSCHAFT; D-67056 Ludwigshafen (DE).</b></p>	<p>(81) Bestimmungsstaaten: <b>AL, AU, BG, BR, BY, CA, CN, CZ, GE, HU, ID, IL, JP, KR, KZ, LT, LV, MK, MX, NO, NZ, PL, RO, RU, SG, SI, SK, TR, UA, US, eurasisches Patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</b></p> <p><b>Veröffentlicht</b> <i>Mit internationalem Recherchenbericht. Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist; Veröffentlichung wird wiederholt falls Änderungen eintreffen.</i></p>
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<p>(54) Title: <b>USE OF SHAPED BODIES AS A CATALYST FOR THE PRODUCTION OF CAPROLACTAM</b></p> <p>(54) Bezeichnung: <b>VERWENDUNG VON FORMKÖRPERN ALS KATALYSATOR ZUR HERSTELLUNG VON CAPROLACTAM</b></p> <p>(57) Abstract</p> <p>The invention relates to the use of essentially shaped bodies containing a catalytically active oxide as a catalyst comprising no soluble constituent, under the reaction conditions, for the production of cyclic lactams by reacting aminocarboxylic acid nitriles with water in aqueous phase, in a fixed bed reactor. This catalyst is composed of shaped bodies which can be obtained by shaping the oxide into shaped bodies and by treating the oxide with an acid which is hardly soluble, having 0.1 to 30 % by weight of the oxide, before or after the shaping process.</p> <p>(57) Zusammenfassung</p> <p>Verwendung von im wesentlichen ein katalytisch aktives Oxid enthaltenden Formkörpern als Katalysator, welcher unter den Reaktionsbedingungen keine löslichen Bestandteile aufweist, zur Herstellung cyclischer Lactame durch Umsetzung von Aminocarbonsäurenitrilen mit Wasser in flüssiger Phase in einem Festbettreaktor, wobei der Katalysator aus Formkörpern besteht, die erhältlich sind durch Formen des Oxids zu Formkörpern und Behandeln des Oxids vor oder nach dem Formen mit 0,1 bis 30 Gew.-% bezogen auf das Oxid einer Säure, in der das Oxid schwerlöslich ist.</p>				

USE OF SHAPED BODIES AS A CATALYST FOR THE PRODUCTION OF  
CAPROLACTAM

Specification

The present invention relates to the use of shaped articles essentially comprising a catalytically active oxide as a catalyst for preparing cyclic lactams by reacting aminocarbonitriles with water.

10 OZ.0050/44458 discloses the use of shaped articles having no soluble constituents under the reaction conditions as a catalyst for preparing cyclic lactams by reacting aminocarbonitriles with water in the liquid phase in a fixed bed reactor. The catalysts, which can comprise a multiplicity of oxides, selenides, tellurides and phosphates, are obtainable, for example, by extruding powders of the corresponding compounds.

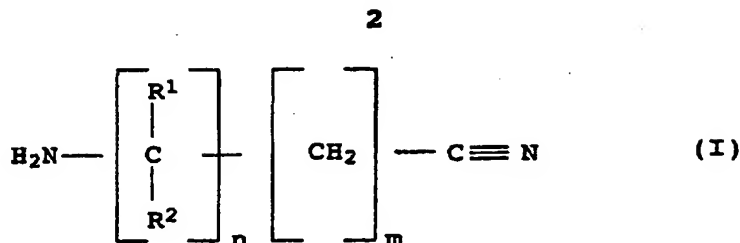
It is true that the shaped articles afford cyclic lactams, but selectivity and yield are not fully satisfactory, especially at short residence times which make a high space-time yield possible and so make it possible to make the reactors smaller.

20 It is an object of the present invention to provide a method of using shaped articles having no soluble constituents under the reaction conditions as a catalyst for preparing cyclic lactams by reacting aminocarbonitriles with water in the liquid phase in a fixed bed reactor without the above-described disadvantages.

We have found that this object is achieved according to the present invention by a method of using shaped articles essentially comprising a catalytically active oxide as a catalyst which has no soluble constituents under the reaction conditions for preparing cyclic lactams by reacting aminocarbonitriles with water in the liquid phase in a fixed bed reactor, said catalyst consisting of shaped articles obtainable by shaping the oxide into shaped articles and, before or after said shaping, treating the oxide with from 0.1 to 30% by weight, based on the oxide, of an acid in which the oxide is sparingly soluble.

30 Preferred embodiments of the method of use of the present invention are revealed in the subclaims.

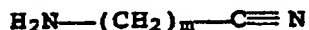
The starting materials used in the process of the present invention are aminocarbonitriles, preferably those of the general formula I



where  $n$  and  $m$  are each 0, 1, 2, 3, 4, 5, 6, 7, 8 or 9 and  $n + m$  totals at least 3, preferably at least 4.

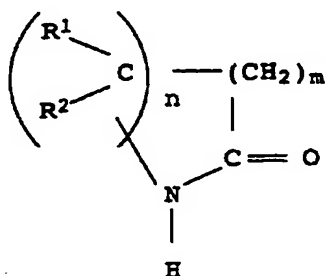
$\text{R}^1$  and  $\text{R}^2$  can in principle be substituents of any type. It is merely necessary to ensure that the desired cyclization reaction is not affected by the substituents. Preferably,  $\text{R}^1$  and  $\text{R}^2$  are independently  $\text{C}_1$ - $\text{C}_6$ -alkyl or  $\text{C}_5$ - $\text{C}_7$ -cycloalkyl or  $\text{C}_6$ - $\text{C}_{12}$ -aryl.

Particularly preferred starting compounds are aminocarbonitriles of the general formula



where  $m$  is 3, 4, 5 or 6, especially 5. When  $m = 5$ , the starting compound is 6-aminocapronitrile.

In the process of the present invention, the above-described aminocarbonitriles are reacted with water in the liquid phase using heterogeneous catalysts to form cyclic lactams. Use of aminocarbonitriles of the formula I results in the corresponding cyclic lactams of the formula II



where  $n$ ,  $m$ ,  $\text{R}^1$  and  $\text{R}^2$  are each as defined above. Particularly preferred lactams are those where  $n$  is 0 and  $m$  is 4, 5 or 6, especially 5 (caprolactam being obtained in the latter case).

The reaction is carried out in the liquid phase at generally from 140 to 320°C, preferably at from 160 to 280°C; the pressure is generally within the range from 1 to 250 bar, preferably from 5 to 150 bar, it being necessary to ensure that the reaction

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mixture is predominantly liquid under the conditions employed. The residence times are generally within the range from 1 to 120, preferably 1 to 90, and especially 1 to 60, min. In some cases, residence times of from 1 to 10 min have proven to be completely  
5 adequate.

The amount of water used per mole of aminocarbonitrile is generally at least 0.01 mol, preferably within the range from 0.1 to 20 mol, especially within the range from 1 to 5 mol.

10

The aminocarbonitrile is advantageously used in the form of a from 1 to 50% strength by weight, especially from 5 to 50% strength by weight, particularly preferably from 5 to 30% strength by weight, solution in water (in which case the solvent  
15 is also reactant) or in water/solvent mixtures. Examples of usable solvents are alkanols such as methanol, ethanol, n- and i-propanol, n-, i- and t-butanol and polyols such as diethylene glycol and tetraethylene glycol, hydrocarbons such as petroleum ether, benzene, toluene, xylene, lactams such as pyrrolidone or  
20 caprolactam, or alkyl-substituted lactams such as N-methyl-pyrrolidone, N-methylcaprolactam or N-ethylcaprolactam, and also carboxylic esters, preferably of carboxylic acids having from 1 to 8 carbon atoms. Ammonia can also be present in the reaction. Mixtures of organic solvents can also be used. Mixtures of water  
25 and alkanols in a water/alkanol weight ratio of 1-75/25-99, preferably 1-50/50-99, have been found to be particularly advantageous in some cases.

It is in principle equally possible to use the aminocarbonitriles  
30 as solvent as well as reactant.

The catalytically active oxides used can be, for example, acidic, amphoteric or basic oxides, preferably aluminum oxide, such as alpha- or gamma-alumina, tin oxide, zinc oxide, cerium oxide,  
35 especially titanium dioxide, amorphous, as anatase or rutile, and also their mixtures and mixed phases.

The aforementioned compounds can be doped with, or comprise, compounds of main groups 1 to 7, especially 2, 3 or 4, of the  
40 periodic table, of transition groups 1 to 7 of the periodic table, of the elements of the iron group or of the lanthanides or actinides and also mixtures thereof.

If desired, these catalysts may comprise up to 50% by weight in  
45 each case of copper, tin, zinc, manganese, iron, cobalt, nickel, ruthenium, palladium, platinum, silver or rhodium.

These catalytically active oxides are preparable in a conventional manner, for example by hydrolysis of the corresponding organics, alkoxides, salts with organic or inorganic acids and subsequent heating or calcining and also  
5 advantageously, especially in the case of titanium dioxide, pyrogenically and are generally commercially available.

According to the invention, the oxides are treated with an acid before or after shaping. Suitable acids include organic acids  
10 such as acetic acid, oxalic acid, propionic acid, butyric acid, maleic acid or inorganic acids such as isopolyacids, heteropolyacids, sulfuric acid or hydrochloric acid. Particularly suitable catalysts are obtainable by treatment with acetic acid, formic acid, nitric acid, especially phosphoric acid or  
15 polyphosphoric acid.

It is also possible to use mixtures of acids.

The treatment can be carried out continuously or batchwise in one  
20 or more stages. The individual stages can be carried out with the same acid, different acids or identical or different mixtures of acids.

Similarly, the oxides can be treated with an acid in the form  
25 mentioned before and after shaping.

Preferably, the oxides are treated with an acid before shaping.

The amount of acid used according to the invention is from 0.1 to  
30 30%, preferably from 0.1 to 10%, especially from 0.1 to 5%, by weight, reckoned as pure acid, based on pyrogenic titanium dioxide. The acid can be mixed with a liquid diluent, such as water.

35 The catalysts can be prepared from the oxides without additives. It is similarly possible to add additives such as binders, for example titanium dioxide sols, salts of the oxides used, soluble titanium salt compounds, hydrolyzable titanium compounds such as titanium alkoxides or aluminum salts, such as pore-formers, for  
40 example methylcellulose, carbon fibers, fibers of organic polymers, melamine, starch powder, preferably before shaping.

The shaped articles can be present in various forms, for example as ball, tablet, cylinder, hollow cylinder, pellet, granule or  
45 strand. Such shaped articles are preparable in a conventional manner using appropriate shaping machines such as tableting

machines, extruders, rotary granulators, pelletizers or combinations thereof.

The shaped material, if desired after an acid treatment, is  
5 advantageously dried, especially at from 20 to 120°C, preferably in an inert gas atmosphere or in the air, and then calcined, especially at 400-700°C, preferably in an inert gas atmosphere or in the air.

10 The heterogeneous catalysts are arranged in a fixed bed. The reaction can take place in a conventional manner, for example in a downflow or preferably upflow mode, especially continuously, by bringing the reaction mixture into contact with the catalyst bed.

15 The advantage of the process of the present invention is the possibility to operate the cyclization continuously in a simple manner with very high throughputs and high yields and selectivities and short residence times. Since the catalysts used have a long lifetime from observations to date, the result is an  
20 extremely low catalyst consumption.

Example 1: Preparation of pyrogenic titanium dioxide extrudates  
(formic acid)

25 8350 g of pyrogenic titanium dioxide powder having a rutile/anatase ratio of 80/20 were kneaded for 3 hours with 47 g of 85% strength formic acid and 3750 g of water and thereafter molded into 4 mm extrudates under a molding pressure of 70 bar. The extrudates were dried at 120°C for 16 hours and then calcined  
30 at 500°C for 3 hours.

Analysis of extrudates:

Density	989 g/l
35 Water regain	0.31 ml/g
Cutting hardness	25 N
Surface area	37 m <sup>2</sup> /g

Example 2: Preparation of pyrogenic titanium dioxide extrudates  
40 (phosphoric acid)

1950 g of precipitated titanium dioxide powder (anatase) were kneaded for 3 hours with 60 g of concentrated phosphoric acid and 900 g of water and then molded into 1.5 mm extrudates under a  
45 molding pressure of 70 bar. The extrudates were dried at 120°C for 6 hours and then calcined at 350°C for 5 hours.



## Analysis of extrudates:

Density	722 g/l
Water regain	0.46 ml/g
5 Surface area	204 m <sup>2</sup> /g

Example 3: Preparation of pyrogenic titanium dioxide extrudates  
(nitric acid)

- 10 11,000 g of precipitated titanium dioxide powder (anatase) were kneaded for 2 hours with 420 g of concentrated phosphoric acid and 3650 g of water and then molded into 3 mm extrudates under a molding pressure of 70 bar. The extrudates were dried at 120°C for 6 hours and then calcined at 320°C for 2 hours and at a 350°C for 15 a further 3 hours.

## Analysis of extrudates:

Density	919 g/l
20 Water regain	0.32 ml/g
Cutting hardness	25 N
Surface area	105 m <sup>2</sup> /g

- 25 Examples 4 to 16: Conversion of 6-aminocapronitrile into caprolactam

- 30 A solution of 6-aminocapronitrile (ACN) in water and ethanol in the weight ratios reported in the table was passed into a 25 ml capacity heated tubular reactor (diameter 6 mm; length 800 mm) packed with catalysts 1 to 4 recited in the table, in the form of granules. The product stream leaving the reactor was analyzed by gas chromatography. The results are recited in the table as examples.

- 35 As well as caprolactam, the product stream comprises essentially ethyl  $\epsilon$ -aminocaprylate and  $\epsilon$ -aminocaprylamide. Both can likewise be cyclized to form caprolactam. In addition, the stream includes from 5 to 8% of caprolactam oligomer which can be cracked to form caprolactam monomer.

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Table

Ex.	Catalyst	ACN [% by wt.]	Water [% by wt.]	Molar ratio ACN/H <sub>2</sub> O [%]	Ethanol [% by wt.]	Temp. [°C]	Residence time [min]	ACN conversion [%]	Capro selec- tivity [%]
4	1	10	3.2	2	86.8	230	21	99	89
5	1	10	3.2	2	86.8	230	8	99	92
6	1	10	3.2	2	86.8	230	5	99	88
7	2	10	3.2	2	86.8	180	30	93	93
8	2	10	6.4	4	83.6	180	30	92	92
9	2	10	3.2	2	86.8	230	10	100	93
10	2	10	6.4	4	83.6	230	10	100	91
11	3	10	3.2	2	86.8	230	22	99	88
12	3	10	3.2	2	86.8	230	9	99	92
13	3	10	3.2	2	86.8	230	5	96	90
14	4	10	3.2	2	86.8	230	20	100	91
15	4	10	3.2	2	86.8	230	8	96	92
16	4	10	3.2	2	86.8	230	5	87	90

Catalysts 1 to 4 were prepared similarly to catalyst examples 1 to 3:

- 5 Catalyst 1: Precipitated titanium dioxide extruded with 3% of phosphoric acid as 3 mm extrudates and then ground to granules 1.0-1.5 mm in size
- 10 Catalyst 2: Precipitated titanium dioxide extruded with 3% of phosphoric acid as 3 mm extrudates
- Catalyst 3: Pyrogenic titanium dioxide extruded with 3% of phosphoric acid as 4 mm extrudates and then ground to granules 1.6-2.0 mm in size
- 15 Catalyst 4: Pyrogenic titanium dioxide extruded with 0.5% of formic acid as 4 mm extrudates and then ground to granules 1.6-2.0 mm in size

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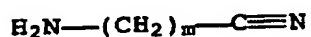
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We claim:

1. The method of using shaped articles essentially comprising a catalytically active oxide as a catalyst which has no soluble constituents under the reaction conditions for preparing cyclic lactams by reacting aminocarbonitriles with water in the liquid phase in a fixed bed reactor, said catalyst consisting of shaped articles obtainable by shaping the oxide into shaped articles and, before or after said shaping, treating the oxide with from 0.1 to 30% by weight, based on the oxide, of an acid in which the oxide is sparingly soluble.

2. The method of claim 1, wherein the reaction is carried out at a temperature within the range from 140 to 320°C.

3. The method of either of claims 1 and 2, wherein the aminocarbonitriles used have the formula



where

- m is 3, 4, 5 or 6.

4. The method of claim 3, wherein the aminocarbonitrile used is 6-aminocapronitrile.
5. The method of any of claims 1 to 4, wherein the aminocarbonitrile is used in the form of a from 1 to 50% strength by weight solution in water or in water/org. solvent mixtures.
6. The method of any of claims 1 to 5, wherein the catalytically active oxide is titanium dioxide, aluminum oxide, tin oxide, zinc oxide, cerium oxide or a mixture thereof.
7. The method of any of claims 1 to 6, wherein the acid used is phosphoric acid or polyphosphoric acid.
8. The method of any of claims 1 to 7, wherein the acid used is nitric acid, acetic acid or formic acid.